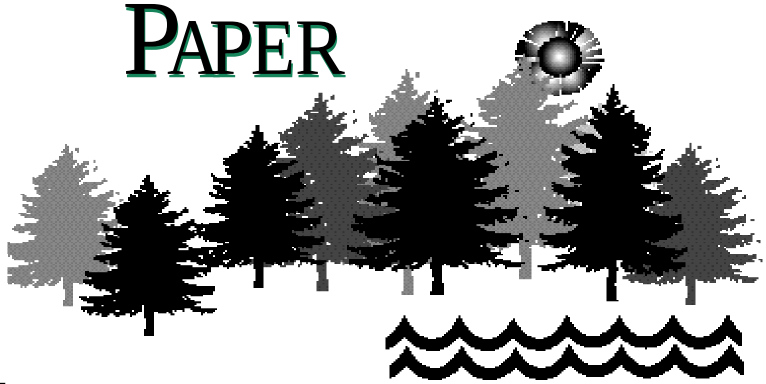
GREEN PAPER



Clean Water: A Fragile Resource

by Richard Middleton

Water is the fundamental ingredient of life on this planet. We can survive without food for several weeks, but without water we die within a few days. In our modern economies, water is also essential for agriculture, industry, power generation, and transportation.

One would expect that water would be treasured, used carefully, and guarded against harm. In fact, it is squandered, polluted, and abused. Nearly half the world's population, virtually all in developing countries, suffers from diseases resulting from insufficient or contaminated water. According to the World Health Organization, 2 thousand-million people are at risk from waterborne and food-borne diarrhoeal diseases, which are the main cause of more than 5 million child deaths each year.

Increasingly, water resources are being polluted by untreated industrial wastes or being exploited beyond their renewable capacity. If we do not make radical changes in the way in which we use water, we may find that it is no longer usable, at least not without specialized treatment, which is beyond the economic resources of many countries.

Many people are aware of the pollution and environmental problems that too often follow from industrialization, but have not yet realized some important implications. The majority of the world's population lives in developing countries; if the people of these countries are to have proper water supplies, and if the economies of these countries are to expand and industrialize, existing problems must be remedied. However, water supply cannot be considered in isolation. Inadequate waste disposal pollutes water sources, often beyond remedy. Shortfalls in other basic services — poor storm drainage, poor collection of solid wastes — also make people's lives miserable. So although this paper focuses mainly on water and sanitation, in the long term it is essential to think in terms of integration of urban environmental services into a comprehensive package of water, sanitation, drainage, and solid wastes management.

WATER AVAILABILITY — AND SCARCITY

Water is the most abundant element on Earth, covering over 70 percent of its surface and totalling about 1.4 thousand-million cubic kilometers. Spread evenly over the planet, it would form a layer nearly 3 kilometers deep. However, only a very small proportion of this total, perhaps 0.003 percent, is actually usable. Most of the water, about 97 percent, is in the oceans or inland seas and is too saline for most purposes. Of the remaining 3 percent, almost all — about 87 percent — is locked up in the polar ice caps or deep underground.

In an average year, this still leaves over 40,000 cubic kilometers of fresh water available from the rivers of the world, compared to present total abstractions of only a little over 3,000 cubic kilometers per year. This availability (equivalent to over 7,000 cubic meters per person) may seem enough to ensure ample supplies for everyone, but this water is often in the wrong place. The Amazon basin, for example, has ample resources, but it is uneconomical to export this water to the places where it is needed.

In addition, rainfall can be highly erratic, so that actual supplies may be far lower than these average figures. In monsoon climates, rain is intense but usually occurs for only a few months each year; expensive dams and reservoirs are needed to store water for the dry months and to minimize flood damage. Even in these “wet” climates, year-to-year fluctuations can reduce supplies significantly. In dry areas such as the African Sahel, prolonged droughts result in crop failures, death of livestock, and widespread misery and starvation.

The allocation and use of water is a contentious, often emotional, issue. Disputes about water may be within one country, regional, or affecting much of a continent. In Africa, for example, more than 57 major rivers or lake basins are shared by two or more countries: five are shared by six or more countries; the Nile, by nine; and the Niger, by 10. Worldwide, more than 200 river systems, covering over half the land surface, are shared by two or more countries. In addition, many major aquifers extend across national borders, and abstraction by one country can lead to political tensions with its neighbors.

As good quality and affordable water becomes scarcer, these disputes could become more heated. Worldwide, it is estimated that 20 countries, almost all in the developing world, already have renewable water resources below 1,000 cubic meters per person, a level commonly agreed to represent a severe constraint on development, and another 18 countries have resources below 2,000 cubic meters per person.

Added to this, the world’s population, now more than 5.3 billion, may reach 8.5 billion by the year 2025. Some experts estimate that the level at which the population will stabilize may be as high as 16 million people. Whatever the final figure, it is clear that immense pressure will be placed on Earth’s limited resources. And the highest population growth rates often occur in precisely those areas in which water resources are under most pressure — the countries of the developing world.

In recent years, most population growth has been concentrated in urban areas. Overall population growth in the developing countries is about 2.1 percent annually, but urban areas are growing by more than 3.5 percent. Urban slums or squatter settlements that absorb the poorest of the new urban dwellers are growing at an estimated 7 percent a year.

Peripheral squatter settlements are often precariously established on land not wanted for any other purpose, such as unstable steep hillsides or low-lying areas prone to flooding. They do not conform to any urban plans in terms of layout or standards. Because they are illegal and “temporary,” municipal authorities usually are not quick to provide infrastructure such as roads, schools, health clinics, water supply, and sanitation. Yet these settlements will unavoidably be the pattern for much of the city that future infrastructure must serve; this has important implications for both the technical and institutional solutions that will be needed if services are to reach everyone and be sustainable.

In some countries, the major problems with water supply stem not only from the absolute scarcity of water in relation to population but from the adoption of mistaken policies with regard to water and adherence to them long after their adverse effects have become obvious. So although additional investment in the sector is needed, it must be accompanied by change: The first priority must be to make the best use of the substantial investments already going into the sector every year.

USE — AND ABUSE — OF WATER RESOURCES

Irrigated agriculture is the major user of water resources. Typically, over 80 percent of available water is devoted to agriculture. But because water has usually been supplied free or at heavily subsidized rates, there has been little incentive to use it efficiently, and the revenues, if any, are not enough to ensure proper maintenance. The result has been very inefficient use — efficiencies probably average below 40 percent worldwide — and progressive deterioration of many of the larger systems.

Efficiency could be substantially improved by better operation and maintenance of the systems — repairing canals, levelling fields to ensure even water distribution, matching releases from reservoirs to actual downstream needs, and managing the water more effectively once it reaches the farms — or by adopting new, more efficient techniques such as drip irrigation. Such improvements are vital in view of the overwhelming impact of irrigation demands and in fairness to urban areas struggling to maintain adequate supplies. According to Sandra Postel of the Worldwatch Institute, an expert on water use: “Raising irrigation efficiencies worldwide by just 10 percent would save enough water to supply all global residential water uses."

The misuse of water is particularly unfortunate because it is not always accompanied by the expected increase in agricultural productivity. Failure to provide proper drainage to irrigated areas (saving money in the short term) leads to problems with waterlogging and salinity and to the eventual loss of productivity.

- The United Nations Food and Agriculture Organization estimates that, because of salinity or poor drainage, as much as 45 million hectares of irrigated land in developing countries requires reclamation — almost half of the 92 million hectares of irrigated land in the developing world.
- In several countries, waterlogging and soil salinization have removed nearly as much irrigated land from production as has been opened by new irrigation projects in recent years.
- In Egypt, a land-scarce economy, almost half of the cultivated area — mainly in the western part of the Nile Delta — has salinity levels sufficient to affect crop production, reduce yields, and lead to the temporary or permanent abandonment of irrigated areas.
- One estimate puts the annual loss of output in Mexico due to salinization at 1 million tons of food grains, sufficient to provide basic rations for 5 million people.

Industry uses much less water than irrigation, but its impact may be severe for two reasons. First, industrial use of water often is not governed by a national water resources policy, and so tends to be excessive. Second, discharge of untreated industrial wastes may make surface and groundwater too dangerous for safe consumption.

Industrial use of water also is often very inefficient. Unable to supply industrial needs through municipal systems and anxious to encourage economic growth, many countries have allowed industries to develop private water systems. The cost of this water is often low, and, because it forms only a small fraction of total manufacturing costs, there is no incentive for conservation. For example, in Bangkok, Thailand, which suffers from severe overdraft of groundwater, water from the metropolitan waterworks authority would cost industry eight times as much as private pumping of groundwater.

The volumes of water used in manufacturing can vary widely, depending on the industrial processes adopted and the extent of recycling. Manufacturing a ton of steel may take as much as 190,000 liters or as little as 4,750 liters, and a ton of paper may take 340,000 liters or 57,000. Proper regulation of abstraction and charging the true cost of the water would stimulate more efficient use without having a marked effect on manufacturing costs. Water costs, even in countries where tariffs reflect the full costs of the resource, rarely comprise more than a small fraction (1 to 3 percent) of the cost of industrial production. Even in "water-intensive" industries, the proportion of water actually used is small — typically around 20 percent in food processing, 25 percent in paper manufacturing, and 33 percent in textiles. The balance is either recycled (increasingly the case in industrialized countries) or discharged as effluent. More realistic tariffs, although important for better sustainability of the sector, are therefore not an effective incentive to more efficient use. More important are strict water allocations and stringent pollution control requirements. For example, Israel has water-use standards for various industries and allocates water accordingly. As a result, in that country the average water use per unit of industrial production has dropped by 70 percent over the last two decades.

Industrial wastewater is often discharged without any form of treatment. It may be dumped directly into rivers and streams, polluting them and eventually the marine environment, or it may be allowed to seep into groundwater. The damage that these discharges cause is out of proportion to their volume. Many modern chemicals are so potent that trace contamination may make huge volumes of water unsuitable for drinking without special treatment.

The remedy is prevention, not cure. As noted in a report of the World Bank and the European Investment Bank, *Industrial Pollution in the Mediterranean:* "Improvements in operating efficiency and resource recovery are far more likely to yield higher returns than expensive end-of-pipe treatment, since some pollution problems are directly attributable to operation and maintenance problems and inadequate incentives for resource conservation and recovery."

The two organizations' assessment of the environmental problems of the Mediterranean found that primary treatment of industrial wastes would cost only 10 to 20 percent of the cost of full treatment but would remove 50 to 90 percent of the most dangerous pollutants. Effective industrial waste discharge reduction, including this primary treatment, would probably have greater environmental impact than insisting on full treatment of the much smaller volume of municipal wastes.

To focus attention on the poor level of service in the water sector, the United Nations named the 1980s as the

TABLE 1: WATER SUPPLY AND SANITATION SERVICE COVERAGE IN DEVELOPING COUNTRIES

POPULATION, MILLIONS	1980			1990		
	Total	Not served (water supply)	Not served (sanitation)	Total	Not served (water supply)	Not served (sanitation)
Urban	933	213 (23%)	292 (31%)	1,332	243 (18%)	377 (28%)
Rural	2,303	1,613 (70%)	1,442 (63%)	2,659	989 (37%)	1,364 (51%)

Source: Achievements of the International Drinking Water Supply and Sanitation Decade 1981 -1990. *Report A/45/327, United Nations Economic and Social Council, July 1990, with minor corrections according to Kinley, David, "Running Just to Stay in Place,"* Choices, *Vol. 2, No.4, December 1993.*

"International Drinking Water Supply and Sanitation Decade." There were some significant improvements, especially in providing service to poor people, but achievements, expressed in terms of coverage, were not as dramatic as had been hoped. As table 1 shows, by the end of the decade, although many more people were being served, the absolute numbers of people in urban areas who were without service had actually increased.

It should be noted that the statistics in table 1 are almost certainly overoptimistic. For example, they do not reveal the quality of service, which can be poor and a threat to the environment and to public health. Too often, the statistics assume that systems, once constructed, remain in good working order, but this may not be true.

The problem is not just that there is insufficient water; the water that is available is not managed properly or distributed evenly.

■ A very high proportion of the supply is lost through leaks. Reviewing many years' experience, the World Bank found that unaccounted-for water (UFW — water that is produced but not paid for because of leaks or "administrative losses") averaged 35 percent of total supply. Increasing water sales from 65 percent to, say, 85 percent would be a cost-effective 30 percent improvement over present conditions.

■ Often, most available water is used by only a few large consumers. In one city, 15 percent of metered connections accounted for 85 percent of consumption. The top 6 percent of households used over 30 percent of domestic consumption; the top 0.1 percent used over 6 percent. Just three industrial connections accounted for almost half the total industrial consumption.

■ These users pay far too little for service. The average cost of the water produced by water supply projects financed by the World Bank in the period 1966-81 was about $1.29 per 1,000 gallons. (A gallon is equivalent to 3.8 liters.) The average tariff was about $0.69 per 1,000 gallons. Since the average level of unaccounted-for water was about 35 percent, the effective price was about $0.45 per 1,000 gallons — about one-third of the cost of producing the water.

■ The rest of the people have to use expensive alternatives. Notes Dale Whittington and his colleagues in *Water Vending and Development: Lessons From Two Countries,* "Households which purchase water from vendors paid two to six times the average monthly amount of households with private connections, for one-tenth as much water."

Because of these problems, water companies in some developing countries lead a hand-to-mouth existence. Politically-controlled tariffs are too low to cover costs; even so, many water bills remain unpaid, so preventive maintenance is neglected. Cities therefore go through cycles: Key rehabilitation is postponed until the system is on the verge of breakdown, at which time another round of massive investment in new works begins. This, in turn, will, because of its debt service requirements, constrain the municipality for the indefinite future.

It is usually easier to obtain funds for building new supply systems, which politically are highly visible, than for repairing existing assets that have deteriorated. The emphasis on expanding supply, and the absence of national water resources policies requiring more efficient use of water allocations, has led to severe overdrawing of aquifers in many countries, with serious but predictable consequences — water scarcity, water tables falling below the pump inlets, and salt water being drawn into aquifers and making them useless for drinking or irrigation.

■ In parts of Tamil Nadu state in southern India, where there are no laws regulating tubewell installation or limiting groundwater withdrawals, groundwater levels dropped 24 to 30 meters during the 1970s as a result of uncontrolled pumping for irrigation.

■ At a recent conference, the representative from one small arid country reported that 240,000 private wells, drilled without reference to

Table 2: Possible Disease Reduction Through Better Water Supply and Sanitation

Disease	Estimated cases/year in developing countries (excluding China)	Potential reduction through improved water supply and sanitation, million cases (%)
Diarrhea	875 million	225 million (26%)
Ascariasis (roundworm)	900 millon	260 millon (29%)
Guinea worm	4 million	3 million (78%)
Hookworm	800 million	615 million (77%)
Trachoma	500 million	135 million (27%)

**Because of data limitations, all figures are for morbidity — the incidence of disease — not mortality. In addition, it should be noted that some measures may reduce mortality but not morbidity.*

Source: Based on data given in Esrey, Steven A. et al.: Health Benefits From Improvements in Water Supply and Sanitation. *Technical Report No. 66. Arlington, Va.: Water and Sanitation for Health Project, July 1990.*

aquifer capacity, were resulting in overdraft and increasing salinity.

This abuse of water resources is not confined to developing countries; over-exploitation of resources is a serious problem in many areas of the United States. One-fifth of all irrigated land in the United States depends on the Ogallala Aquifer, which receives hardly any natural recharge. Over the past four decades, the systems depending on the aquifer expanded from 2 million hectares to 8 million, and some 500 cubic kilometers of water has been withdrawn. The aquifer is now half depleted under a number of states.

Water resources are also deteriorating in quality. Besides pollution from untreated municipal and industrial wastes, they are heavily contaminated by runoff from agricultural areas. For example, in the western United States, the lower Colorado river is now so saline as a result of irrigation return flows that it is virtually useless to Mexico, and the United States is having to build a very large desalting plant at Yuma, Arizona, to improve the river quality.

The situation in urban sanitation is far worse than in water supply. Many of those “served” make do with water closets (WCs) that are rarely flushed because water is so scarce, with septic tanks that overflow because emptying services are unreliable, or with other equally unsatisfactory and unsanitary facilities. Even where these do not cause problems for the users themselves, they are often hazardous to other people and a threat to the environment, because the wastes are discharged without treatment.

These are the problems for those people receiving service. However, about 30 percent of people in urban areas simply do not have any form of adequate sanitation. That means that, in a city of 10 million people, each day about 750 tons of excreta is not collected and accumulates somewhere — perhaps 250,000 tons a year of pathogenic material on the streets and public places or in watercourses.

The combination of inadequate coverage, poor service, and inadequate sewage treatment results in appalling living conditions. Streets and public areas are fouled with excreta, watercourses carry septic sewage, and the piped water supply is intermittent, so sewage seeps into the pipes during the hours when they are not under pressure. The impact, especially on children, is horrendous. Even apparently healthy people are not as productive as they should be because of intestinal parasites. The potential benefits of providing better water supply and sanitation are very high, as table 2 indicates.

The economic costs of avoidable illness and death must be high but are not easily estimated. System deficiencies also involve consumers in other sorts of costs. In Jakarta, Indonesia, it is estimated that $20 million to $30 million is spent each year on boiling water to make it safe for consumption. If this amount of money were spent instead on improving the water supply itself, it could have a significant and lasting impact.

Table 3 gives approximate estimates of the cost of providing conventional services only to those who do not have any service at present. Sector investments in water and sanitation during the 1980s probably averaged about $10 thousand-million per year. If these investments continued at the same rate in the succeeding four years, then the figures in table 3 indicate a need for investments of about $67 thousand-million per year over the next five years just to catch up with the service backlog, without remedying past deficiencies.

With proper management, water is an amazingly inexpensive commodity. In the United States, where the level of service is generally very high, people still complain about their water and

Table 3: Estimated Capital Cost of Providing New Water Supply and Sewerage Services*

	1990 population served, millions	2000 total population, millions	Additional population to be served, millions	Assumed unit cost, $/person	Total cost, $ millions
Urban water supply	1,089	1,900	811	130	105,000
Urban sewerage	955	1,900	945	350	331,000
				TOTAL	436,000

**These figures understate the actual amounts needed to establish and maintain universal coverage. Since past emphasis has been on new construction, many systems are inoperative or seriously deficient and need to be rehabilitated, adding substantially to financial requirements. The estimates also omit the large investments needed to address environmental protection measures.*

Source: Population figures from Achievements of the International Drinking Water Supply and Sanitation Decade 1981-1990*, Report A/45/327, United Nations Economic and Social Council, July 1990. Per capita unit costs in 1990 dollars are derived from World Bank appraisal and project reports. These estimates assume full in-house plumbing and conventional centralized sewerage systems. They are only indicative and should not be used to predict costs for a particular area.*

sewer bills, but perhaps without reflecting on what they receive for their money or comparing this service to almost any other commodity. In the area served by the Washington Suburban Sanitary Commission (Washington, D.C., and its suburbs), reputedly one of the most expensive in the United States, water supply for an average home costs $2.51 per 3,800 liters — equivalent to only $0.60 per ton. Removal and treatment of sewage costs only $0.90 per ton.

There can only be one conclusion from worldwide experience in this sector: Continuing “business as usual” is not acceptable. Fortunately, the intense emphasis on water supply and sanitation during the past decade has provided us with valuable examples of approaches that work; they now need to be applied more widely.

MOVING FORWARD

The evolution of the water sector in developed countries shows a history of steady progression, from household-level water and sanitation to metropolitan and regional schemes. This should tell us that there is no single technological fix to present problems in the sector. Also, changes in technology have always been accompanied by parallel changes in institutional and financial reforms. This suggests that a range of approaches (offering varying technical, financial, and institutional options) is needed, matching the social and economic characteristics of the people to be served and capable of being upgraded as circumstances change.

It is also important to realize that developing countries need not reproduce the water supply and sewerage systems used by developed countries. Rather, developing countries have an opportunity to build on the lessons of the past and create systems that respond to today’s conditions, and so avoid mistakes that are leading to system failures and environmental problems in industrialized countries.

Three principles underlie sound future development in this sector.

■ **Conservation**. This implies using only sufficient water to meet real needs, without waste. Effective conservation usually involves a package of measures — control of leakage, use of water-saving devices, tariffs discouraging wasteful use, and campaigns to make consumers more aware of the consequences of wasteful use.

■ **Sustainability**. This means using technologies and systems that can be kept in working order with resources available to the community being served, and without excessive reliance on external inputs. These resources include not only financial ones but also the institutional capacity to manage systems and the skills needed to maintain and repair installed equipment. Sustainability includes paying attention to acceptability (using water and sanitation systems that suit people’s preferences) and to community participation (in choosing the technologies to be used and in deciding how they will be managed, as well as in the planning, construction, management, and operation and maintenance, as appropriate). Systems that do not keep working or that are not used by the people they were intended to serve are simply a waste of investment resources.

■ **Circular systems**. With increased population pressure on limited resources, we need to think in terms of “circular” systems, not “linear” ones. It is no longer acceptable for cities or industries to export their pollution downstream, causing problems for someone else. Instead, treated wastewater should be regarded as a valuable resource, with potential for reuse in a variety of applications — for irrigation; for replacement of water abstracted from groundwater aquifers; for injection into coastal aquifers to protect them against saline intrusion;

for industrial use; and, with appropriate safeguards, for domestic use. Equally, the nutrients in wastes should not simply be discarded, causing eutrophication in streams and rivers. “Each day, thousands of tons of basic plant nutrients — nitrogen, phosphorus, and potassium — move from countryside to city in...food.... Worldwide, over two-thirds of the nutrients present in human wastes are released to the environment as unreclaimed sewage,” write the Worldwatch Institute’s Lester Brown and Jodi Jacobson. And, of course, these lost nutrients eventually have to be replaced by fertilizers based on petrochemicals.

The decision-making process also needs to be improved. Too many project proposals are accepted based on low initial capital costs, without taking account of many important factors related to sustainability. At a minimum, decisions should be based on “life-cycle costs,” which include all the costs needed to keep the proposed investment maintained and operating efficiently. There is a strong case, too, for solutions that can be locally fabricated and maintained and that are labor-intensive and so generate employment. Such solutions have a better chance of remaining in operation and thus providing long-term project benefits, while assumed benefits from high-technology solutions often cease after the first minor breakdown that cannot be repaired. Unfortunately, there is often found what has been described as an “unintentional conspiracy” at higher levels in both developed and developing countries that strongly favors sophisticated, “modern” solutions, and a serious dearth of textbooks and similar materials to illustrate more appropriate approaches.

There is also a wide gulf between economic and financial reality in many project analyses. “Discounted cash flow” techniques are used as an economic justification for deferring some capital investments until a putative “second phase.”

This may be sound policy at the national level, but it makes little sense to a local government that has to deal exclusively in financial terms and that may never again have access to concessionary external aid. Similarly, unemployment and underemployment mean that, in economic terms, labor can be “shadow-priced” to a fraction of actual costs — but that does not allow a municipality to pay its workers these low wages. In general, there is a need to bridge the gap between local agencies and those thinking in macroeconomic terms.

Additionally, long-term but often irreversible impacts, such as environmental degradation and resource depletion, need to be valued more realistically, so that it is no longer a commercially sound strategy for industries and cities to overdraw or pollute water.

The health impact of water and sanitation services is a special case of long-term costs and benefits that are often ignored. Unbalanced development (increasing the quantity of water supplied, without making provision for removal of wastewater or without providing even basic sanitation) is politically popular but may not improve health because the environment remains fecally contaminated. Untreated discharge of industrial wastes may lead to health problems many years later. Given that the health impacts of many modern chemicals are unknown, because they have only recently been discovered, industries and other prospective polluters should bear the onus of proving that their intended activities are harmless, especially since many industries discharge potentially harmful chemicals in combinations that environmental protection agencies cannot anticipate and evaluate with the resources at their disposal.

In much of the sector, “the best is the enemy of the good.” Where unrealistic public health codes require houses to have sewer connections, formal permission to install pit latrines is often denied, even though they can provide a high level of hygiene while sewer systems may forever be beyond the capacity of many people. Similarly, insistence on very high standards of wastewater treatment before the effluent can be used for crop irrigation may simply result in illegal irrigation using raw sewage, since the required treatment facilities are not affordable and there is no alternative source of water.

PRACTICAL EXAMPLES

■ Improvements in Irrigation Efficiency. From the perspective of global water resources use, introducing more efficient irrigation techniques (such as the drip irrigation used widely in Israel) is critical. Improving irrigation efficiency can free water for use in adjacent urban areas, as is already being done in certain parts of the United States.

An innovative approach to finding new water resources for municipal use is being tried in the Imperial Valley in California.

The Metropolitan Water District of Southern California (MWD) is financing measures to improve the efficiency of irrigation systems by providing new flow-regulating reservoirs, improving canal linings, and installing more flow monitors. In exchange, MWD will be able to use the 106,000 acre-feet of water saved annually. (An acre-foot is the volume of water that would cover 0.4 hectares to a depth of 0.3 meters.) Similarly, the U.S. city of Casper, Wyoming, pays farmers to line their irrigation ditches and to install water-saving irrigation devices; in turn, the city receives the salvaged water. A city in the state of Utah pays $25,000 for the option to use irrigation water, which otherwise would have a prior claim on releases, during droughts. In return, the city provides the farmers with an amount of hay equivalent to that which they would have been able to grow had they been able to irrigate normally.

Another important aspect of improving irrigation efficiency is recognition of the key role of the “beneficiaries” in establishing the appropriate institutional framework. Until recently, improving irrigation was regarded as essentially an engineering problem: If the correct works were constructed (as designed by technicians from some provincial or national office), all that remained was to teach farmers how to make use of the additional supplies of water. That approach has been severely discredited by failures in the sector; it is now appreciated that, in many cases, farmers already had evolved mechanisms for routing distribution canals, managing water allocations, and resolving disputes, and that building on these existing arrangements is far more likely to succeed than trying to impose an entirely new system from outside.

This approach has been applied in the Philippines since the mid-1970s, and the model developed there has been adapted for use in other Asian countries, including Sri Lanka, India, Indonesia, Thailand, Nepal, and Bangladesh. It is a model that should find increasing application in the urban water supply and sanitation sector, since it is now widely accepted that success in peri-urban communities depends on close consultation with the communities themselves.

■ Better Choices in Industrial Processes. The potential for very large savings by requiring industries to use processes that are water-efficient or that make use of recycling has been noted earlier. Tighter controls over water abstraction by industries (including charging industries a realistic price for the use of these resources) also avoids one reported problem: that industries, faced with laws requiring wastes to have less than a specified concentration of contaminants, find it economical to add fresh water to their waste flows to dilute them, without making any effort to reduce the total load of contaminants.

■ Conservation. Although water supply is an industry, producing and selling a product, on average this industry manages to lose one-third of its product before it reaches the

THE BENEFITS OF CONSERVATION: BOSTON, MASSACHUSETTS

The Boston Metropolitan Water Resources Authority (MWRA) was established in 1985 to provide wholesale water and sewer services in the Metropolitan Boston area to 2.5 million people and more than 5,000 industrial and commercial users.

At that time, average usage was 330 million gallons per day (mgd), 10 percent above the estimated safe yield of 300 mgd. (A gallon is equivalent to 3.8 liters.) In fact, the area had been exceeding its reliable yield for nearly 20 years.

Instead of expensive development of new sources, MWRA undertook a comprehensive demand management program. The results have been dramatic: System usage now averages 260 mgd, well within the safe yield of existing sources and down to the consumption levels of the early 1960s.

The program includes the following elements:

■ **Leak detection and repair**. Some 30 mgd of leakage has been found in the over 9,600 kilometers of mains in local communities and another 5 mgd in MWRA’s 400 kilometers of mains.

■ **Metering**. System supply meters are being rehabilitated, and large retail meters overhauled.

■ **Residential retrofitting and repair**. Installation of water-saving fixtures and a leak detection survey are offered to all 730,000 households in the area. On completion of the field work in November 1993, over 360,000 households had participated, with an estimated saving of about 5 mgd. At a cost of about $9.3 million, this is an extremely cheap “source” of water.

■ **Industrial**. Commercial and institutional audits (combining both energy and water) are offered and the results widely disseminated. Savings of between 10 percent and 25 percent are anticipated through simple changes in equipment, fixtures, and maintenance.

■ **Retrofitting public buildings.** One thousand low-volume flush toilets have been provided for public buildings.

■ **Public information.** Although the program has not relied on behavioral change for its success, an extensive multimedia campaign makes people aware of its goals and achievements.

Conservation is usually thought of as appropriate mainly for cities in very dry or drought-prone areas. This program illustrates how it can also be a very economical solution to the water supply problems of cities in zones that are usually considered “wet.” The payback for individual consumers can be dramatic. One residential building spent $66,000 on retrofitting with water-efficient devices — and saved $120,000 per year. Another institution spent $5,000 over two years — and saved more than $31,000 over the next two.

consumer. In some cities, more than half the water is lost. These high losses make it difficult or impossible to establish satisfactory supply conditions: Providing more water or increasing pressures in dilapidated systems merely leads to more bursts and greater leakage.

Conservation programs normally should comprise activities designed to complement each other. In some developing countries, with old systems in poor condition, the first priority usually has to be given to reducing unaccounted-for water.

This normally is a precondition for establishing better supply conditions, and, until supply conditions start to improve, consumers are often unwilling to participate in the other elements of the program.

UFW reduction campaigns usually are not very expensive compared to the cost of the water saved; they have short pay-back periods even at current tariff levels and are even more attractive when their cost is compared to the alternative, the cost of finding a new water source.

In developing countries, where supplies may be intermittent, an important benefit from reduction in UFW is that it may allow the restoration of 24-hour service. This has immediate health implications, and it avoids the pollution of drinking water caused by sewage leaking into mains during the hours when they are not under pressure. It also saves water: People do not feel obliged to fill every container in the house with water during the supply hours in case the next supply period is delayed or missed. Meters can be used and last better; under intermittent conditions, they can be wildly inaccurate because of compressed air being forced through them as the pipes refill, and also suffer damage from running dry. System monitoring and routine leak detection is also much simpler once a system is charged with water, and it does not require highly sophisticated equipment.

A second step is to require water-using fixtures to be efficient; older designs use far more water than needed. Locally manufactured water-efficient toilets, showers, and faucets should become the only types available on the local market, and incentives should be given for retrofitting.

The United States until recently lagged behind Europe in conservation, but is now launching such programs in large numbers, with remarkable effects. For example, in 1988, San Simeon, California, began a retrofit program to install low-volume flush toilets (LVFTs) and water-saving shower heads. By starting with high-water-use facilities (schools, hotels, hospitals, gas stations), wastewater volume was cut by 25 percent. Extending the program to residential areas and restricting summertime garden watering reduced overall water use and wastewater volume by 50 percent. The effects also included recovery of the water supply aquifer, which had been suffering from over-pumping. Most remarkably, the reduction in the cost of water heating was sufficient by itself to pay for the entire program.

Similarly, a pilot study of a cross-section of households, businesses, and public buildings in Mexico City found that fitting them with low-water-use toilets and shower heads cut water consumption in half. The plumbing codes are now being revised accordingly, and a major retrofitting program is being launched.

In some developing countries, supply conditions can at times be so precarious that talk of water-saving fixtures seems almost ludicrous. However, water wastage can be high, even under these conditions. High-income houses use water-inefficient fixtures, and poor people wash under running taps. More efficient fixtures would be valuable even under present conditions: The rich would use less water while maintaining the standards they expect; the poor could make their limited supplies go further.

A third element in a water conservation program is properly designed tariffs. Water charges should, in principle, increase with increasing consumption, so that a basic amount of water is available at an affordable unit price, but larger amounts (for luxury uses such as garden watering, washing cars, and filling swimming pools) are at progressively higher rates.

Frequently, charges are not based on actual consumption, or, while based on metered consumption, are at a flat or even decreasing unit rate. This is no incentive to conservation. There are, of course, serious issues to be resolved — how to provide affordable service to the poor (where many people may share one connection, perhaps giving the erroneous impression of excessive use), or how to run an effective metering program — but they can be overcome.

Consumer participation and education is a fourth, and absolutely vital, element in a successful conservation program. Water use is an aggregation of numerous daily actions, so changing attitudes and behavior is essential, particularly where present supply conditions are poor or where tariff increases are proposed.

■ Water Treatment Technologies. Many developing countries do not have the financial resources or the personnel to install and operate complicated water treatment systems; even industrialized countries need simple, sustainable technologies for their less-developed regions. Instead of complex filtration systems with various types of filter materials and automated controls, there is a trend toward the use of much simpler technology. One example is the simple "declining rate" filter, in which incoming water is shared equally between several filters and each filter is washed when the water in it begins to back up (indicating clogging of sand or other filter materials). Another simple solution is to use "slow-sand" filters, originally introduced over a century ago in Europe, which have very low filtration rates but virtually no moving parts; biological purification is achieved in the layer of material trapped on the surface of the sand. This can be raked off when it threatens to block the filter.

■ Water Supply Standards . Codes of practice in many developing countries have been inherited from former colonial administrations. While these codes are usually technically sound, they tend to result in over-design, since they were originally intended to be applied in quite different circumstances. Critical review of existing standards may reveal that many more people can be served within the same overall budget.

Computer programs are available that make it easy for designers to examine the effects of setting parameters more appropriate to the community being served, rather than adopting imported criteria. These programs are being applied as a matter of routine in a number of countries (India, the Philippines, Indonesia, China, Burma, Sri Lanka, Thailand, and Pakistan); they enable planners to design cost-effective distribution networks at perhaps half the cost of conventional networks.

A case study from the Philippines, probably typical of 40 systems improved by the Local Water Utilities Administration with World Bank support, reports that design modifications resulted in per capita costs falling from $45 to $25, nearly a 45 percent saving. Typically, these economies result from changes such as allowing smaller diameter pipes where flows are small, lowering minimum pressure requirements where buildings are single-story, and designing for the likely service mix rather than assuming that everyone will be able to afford their own connection.

■ Role of the Community. The Tegucigalpa, Honduras, example (sidebar) is typical of many cases of greater community involvement, which has come to be recognized during the decade as a critical element in long-term sustainability. In urban areas, similar approaches in upgrading schemes have led to the involvement of nongovernmental organizations and community associations. Applied to water supply and sanitation, this has resulted in a variety of wholesale/retail arrangements for water supply to squatter communities and the whole concept of community involvement in planning, construction, and operation of both water and wastes systems.

In particular, "effective demand" should be used to determine service levels. This means that people are offered a variety of levels of service and get what they are prepared to pay for. Ideally, this allows the full costs of service to be recovered directly from those benefitting, unless there is a pressing social case for subsidies.

Of course, the community may choose a solution that planners had not anticipated would be popular. In the Philippines, affordable water supply to low-income people was to be given through public standpipes, even

COMMUNITY-MANAGED ALTERNATIVE WATER SUPPLIES: TEGUCIGALPA, HONDURAS

In Tegucigalpa, Honduras, the spread of *barrios marginales* (squatter areas), many at high elevations that are difficult to reach, has led to severe water shortages. People are forced to pay high rates for small amounts of water bought from vendors.

Honduras's National Water and Sanitation Agency, SANAA, established a special group, the Unit for Barrios Marginales (UEBM), to deal with the problem of water supply for these areas. UEBM helps with the installation of three types of systems:

■ Conventional systems, with new wells serving particular neighborhoods.

■ Wholesale vending of water, for which the community builds a storage cistern, which SANAA supplies either directly from the distribution system or, if the cistern is too inaccessible, by tanker truck. The water then flows by gravity or is pumped to smaller storage tanks throughout the community, and is sold at a rate far below the private vendor rate.

■ Improved rainwater catchments to augment supply during the five-month rainy season.

The key element in these schemes is the role of the Community Water Associations in constructing and administering the systems, which can be fully self-sufficient while providing water at a fraction of the cost of vendor supplies. Most of the income earned goes into a revolving fund to help extend the system to other communities, but some is retained to help with other development projects (such as sanitation or roads) in the original community.

In five years, these schemes have served nearly 50,000 people. However, although these innovative solutions make water much more affordable, the people in the barrios marginales still pay 50 percent more than the typical household connected to the city grid.

though there was far less wastage when people had their own connections. It was found, however, that the people concerned were prepared to pay the full costs of yard connections but nothing toward standpipes. Similarly, in Cochabamba, Bolivia, engineers found that people were willing to pay for more expensive yard connections rather than standpipes. And even with this upgraded service, they are paying 86 percent less than when they had to buy water from vendors.

In another example, people in Kumasi, Ghana, who were not using a WC were asked: “If a WC (connected to a sewer system) and a KVIP (Kumasi Ventilated Improved Pit latrine) each cost the same amount each month, which one would you prefer?” The planners’ expectation was that, if the costs were equal, there would be a clear preference for a WC, but this was not the case: Only 54 percent chose WCs, while 45 percent preferred the KVIP — it did not use water and therefore would function if the water system broke down, and it was simpler and less susceptible to abuse. These investigations had a major impact on the design of the eventual sanitation project.

■ Better Tariff Design and Cost Recovery Mechanisms. Water companies have often used average, or “historical,” costs as a basis for their water tariffs. The result is that their charges are too low, for two reasons. The first is obvious: Due to inflation, costs have increased since the systems were built. The second is somewhat more complex: As increasing consumption forces the water company to expand its water production capacity, the company has to develop new sources, each of which is progressively more expensive than existing sources — as it should be, if the least-cost solutions were chosen when the existing sources were being planned. The company is therefore faced with steadily increasing long-run marginal costs, and its tariffs need to take account of these costs in order to curb excessive consumption and delay the need for development of new and expensive additional supplies.

The magnitude of the increases that will be needed may surprise planners. A World Bank study found that, in real terms (constant dollars), the costs per cubic meter of water for projects approved in 1975-81 were about three times those in projects approved in 1966-71. Repeat projects in the same urban areas showed a tendency for a cost increase per cubic meter of more than 200 percent in real terms between the first and second projects.

In recent years, there has been some progress in moving toward tariffs that reflect the real costs of supply but also achieve social objectives. These tariffs use marginal costing to reflect true resource costs; they increase as consumption increases to discourage waste, and they incorporate “lifeline” rates that help to ensure that poor people can afford at least a basic minimum consumption. Tariffs of this sort should eventually enable water companies to be financially self-sufficient and to operate and maintain their systems without depending on external subsidies.

The use of “effective demand” and the realization that community-based systems have a far better chance of acceptance and hence of improved cost recovery have also led to changes in the way charges are collected.

In one low-income area in Honduras, water during the dry season came from the river or from traditional vendors and cost as much as 50 cents for 10 liters. By establishing a water cooperative and buying water in bulk from the municipality, the cost of water from a neighborhood kiosk was reduced to only 10 cents for 10 liters. The two women heads of households who managed the kiosk were paid from the revenues. Every three months, the kiosk operators were changed, dividing the benefits of employment among several families.

In a community-managed system in Africa, users buy plastic tokens, each valid for one 25-liter unit of water, at shops near the kiosks. The rate is equivalent to three times what the association pays for municipal supply; the surplus finances operation and maintenance, pays back the construction loan, and expands the number of kiosks. The project has created 20 full-time jobs and reduced the cost of water by a factor of 3 to 7 compared to traditional vendors.

THE SANITATION COLLECTION

Almost everyone knows about “the water problem.” Almost no one outside the sector knows that there is a sanitation problem that is at least as serious as the better-publicized water one. There are many close links between water supply and sanitation.

■ Health. Most water-related diseases are actually related to improper collection and disposal of excreta. That is why the estimates of disease reductions in table 2 refer to both water supply and sanitation. Improving one without the other is far less effective.

■ Water use. Older-design flush toilets require 19 liters of water per flush and can account for up to 40 percent of domestic water use. Where total use is 190 liters per capita per day, replacing these toilets with newer units using only 0.7 liters per flush could save 25 percent of domestic water use, with no sacrifice in convenience or health. Conversely, installing 19-liter water-flush units in a house without a WC

ON-SITE SANITATION FOR THE 20TH CENTURY: THE VIP AND PF OPTIONS

The Ventilated Improved Pit (VIP) latrine solves the two major problems of the traditional outhouse: smell and flies. By installing a large-diameter vent pipe leading directly from the pit to above the roof, a strong draft is created up the pipe. Flies are controlled by attaching a screen to the top of the pipe; any flies hatching out in the pit fly up the pipe, are trapped by the screen, and die. If two pits are provided, one may be used for some years until nearly full, then rested for some years while the second is used; by that time, the contents of the first pit have turned into humus, which may be safely dug out and used on the land.

Although originally a rural technology, VIPs have gained wide acceptance in urban areas, especially in Africa. The VIP is very accommodating, accepting a variety of materials that people use to clean themselves after defecating. However, a large part of the world's population uses only water for cleansing, and for them it is possible to install a simple water-sealed unit, which can be flushed by hand using a small quantity of water.

The Pour-Flush (PF) toilet consists of a hydraulically-efficient pan that can be flushed with a few liters of water, connected to a pair of leach pits, used alternately. (As with the VIP, these can be emptied after a few years and the humus used on the land.) Because of the water seal in the pan, it can be installed inside the house. This form of sanitation is very acceptable throughout much of Asia, Latin America, the Middle East, and North Africa. It is comparable in cost to a VIP, again far cheaper than a conventional WC connected to a sewer or a septic tank. It does require some water (about 2 liters per flush), but this is still much less than a conventional WC.

A significant policy decision by the Indian government during recent years was to restrict construction of new sewer systems. The Central Government's Integrated Scheme of Low Cost Sanitation (with funding of about $65 million for the period 1990-97) is helping people in urban areas improve their sanitation by installing PF toilets. For low-income people, 45 percent of the cost of the latrine is an outright grant, and 50 percent is available as a loan; they only have to contribute 5 percent from their own resources.

may add 70 percent to its water consumption. This clearly is not desirable in areas where water is already in short supply, and it adds considerably to the amount of sewage that eventually must be disposed of properly.

■ Costs and cost recovery. The costs of sewage collection, treatment, and disposal rise rapidly as water consumption increases. Planning only for the water supply side of the system, without considering sanitation costs, will leave a city facing either unanticipated high costs or environmental problems.

In 1980, the World Bank reported that, using conventional practice, it cost five or six times as much to get rid of water as to supply it. This was for consumptions of about 150 to 190 liters per capita per day. More recent information, from Indonesia, Japan, Malaysia, and the United States, shows that the ratio rises sharply with increasing consumption; from 1.3 to 1 at 19 liters per capita per day, to 7 to 1 at 190 liters, and 18 to 1 at 760 liters.

It should be noted that sewer charges are typically much lower than water ones, even though sewerage costs are higher.

Also, water utilities have managed to establish some control over the level of charges and can apply sanctions (such as cutting off service) for non-payment. Sewer charges in many developing countries are simply a small part of general municipal tax revenues and are not only too low but also are not collected or, if collected, are diverted to other municipal operations.

■ Water reuse. When water resources are short, wastewater is an obviously attractive source of supply, and it will be used whether this use is officially approved or not. Any increase in water supply is therefore likely to result in increased use of the resulting wastewater, treated or not. The issue that planners have to consider is whether they will also devote the resources to ensure that this reuse is properly managed and does not jeopardize public health.

Given these considerations, there has been much attention paid to devising sanitation systems that are acceptable to the people who will use them, affordable, sustainable, minimize water use, and can safely allow the reuse of treated wastes. The most important sanitation development in the decade has been the legitimizing of forms of sanitation that were once regarded as primitive. After several years of applied research and technological refinements, outhouses have been transformed into simple but sophisticated installations providing a high level of convenience and hygiene. The two major technologies are the Ventilated Improved Pit (VIP) latrine and the Pour-Flush (PF) toilet. These cost far less than conventional toilets connected to septic tanks or sewerage systems; research by the World Bank indicates cost advantages of about 15 to 1.

The VIP latrine and the PF toilet have significant advantages over both traditional on-site systems and conventional sewerage.

■ They are simple, reliable, hygienic, and affordable.

■ They can be constructed of local materials rather than imported ones, require little technical expertise for design, and can be constructed by individuals or communities with only moderate outside help.

- They occupy only a small space, making them suited for congested areas.
- They still work when water is scarce. The VIP needs no water for operation, the PF only 2 liters or so per flush (plus any water used for ablutions), and even this can be sullage (waste water from bathing, laundry, and the like).
- No complex sewage treatment is required; if alternating pits are used, they provide full on-site treatment of wastes and allow safe recovery of nutrients for use on the land.
- They can be upgraded to more elaborate systems.
- Most important, they have proved very acceptable to the people using them.

As water consumption and population density increase, on-site systems can no longer cope with the higher volume of wastes. One traditional solution is the septic tank, providing preliminary treatment to waste before discharging it to underground soakaways, but this is both expensive and liable to failure. The soakaways clog if overloaded, which usually happens because the tank is not emptied properly. As a result, poorly treated effluent is discharged illegally to roadside drains or just forms pools on the surface.

One remedy, developed initially in the United States and Australia but now spreading to developing countries, is the use of solids-free sewerage (SFS). This is a network of small bore pipes (often plastic), laid to carry the effluent from septic tanks to some point where it can be discharged into a trunk sewer or treatment plant. As well as collecting septic tank effluent, SFS can be used in new installations, provided that a simple interceptor tank is constructed to provide primary treatment.

Brazil is one of the countries pioneering developments in lower-cost sewerage. In particular, pilot projects are using "simplified sewerage," which is an adaptation of conventional sewerage using design criteria reflecting current knowledge and materials availability; cost savings of 40 to 50 percent are claimed. The designs allow fewer manholes, shorter design periods, smaller minimum pipe sizes (now that plastic sewers are replacing short clay or concrete pipes), and shallower pipes (since frost is not a hazard in most developing countries).

In the past, emphasis has been on large centralized systems. However, with greater urbanization, it is becoming uneconomical to collect sewage in massive interceptors and convey it to one central point for treatment. Also, given past failures of treatment systems, this could lead to an environmental disaster. A more appropriate solution is to provide decentralized plants, each serving a section of the city. The cost savings can be significant: For Toledo in the state of Parana, Brazil, it was estimated that

REVENUE-EARNING SEWAGE TREATMENT: DUCKWEED-BASED AQUACULTURE

Duckweed systems, like conventional stabilization ponds, depend on a series of treatment processes to achieve a high-quality effluent. After screening (and grit removal, if necessary), the sewage is given simple primary treatment (typically in a pond not used for duckweed production) and is passed to the duckweed pond or to a series of meandering shallow channels in which the duckweed grows; the actual geometry is fairly flexible. From there, the duckweed is transferred to a fish pond or ponds; because of its small size it can easily be scooped or pumped. Yields from intensive aquaculture may be spectacular — up to 20 tons of fish per acre per year — but even moderate outputs (in the three to four tons per acre per year range) can provide a valuable source of protein and income to local communities. (An acre is equivalent to 0.4 hectare.) In Bangladesh, preliminary results suggest that duckweed can be produced at a rate of about 0.5 tons per acre per day of duckweed (wet weight); this, in turn, will produce either 45 kilograms of dried high-protein meal or support fish production equivalent to about 58 kilograms per acre per day.

The banks between the channels of the duckweed pond can be used for cultivation of cash crops, such as lentils or bananas. The overall system can earn substantial revenues. The duckweed can also be dried and used in feed for chickens. In Peru, laying chickens maintained egg production — and produced eggs with better colored yolks, an important selling point — with up to 40 percent of duckweed substituting for commercial feed in their diets. However, this is probably a less efficient way of using the duckweed, and drying may present a problem in many communities and climates.

In all cases, the water emerging from the duckweed pond is fully treated and suitable for discharge into water courses or for irrigation. In fact, it is often considerably cleaner than "fresh" water in the area.

The ability of duckweed to survive in adverse environments suggests other potential uses, although these have not yet been tested in field trials. For example, it can concentrate trace metals in industrial wastes, resulting in effluents suitable for discharge to watercourses and, possibly at the same time, providing an economical way of retrieving valuable resources that would otherwise pollute the environment.

Similarly, because duckweed flourishes in brackish waters, it could potentially be used for treatment of waters with high salt content: polishing groundwater prior to use for irrigation or potable supply; polishing irrigation drainage returns prior to reuse; or, possibly, converting poorly-managed irrigated land on which production has declined due to salinization into duckweed/aquaculture systems with a high cash return.

providing seven treatment plants rather than two would save 15 percent. Such decentralized plants are also less vulnerable to one of the major difficulties with the present uncontrollable urbanization: It is almost impossible to design least-cost solutions for centralized treatment plants, which have a design period of at least 20 years, if planners cannot specify the future pattern of land use in the city.

In many developing countries, sewage is often discharged untreated or passes through malfunctioning treatment plants from which the effluent is not much better than the raw sewage. However, most people do not realize that, even if conventional sewage treatment was provided and was effective, the effluent would still be highly pathogenic; conventional plants are simply not designed to remove pathogens. Since the effluent will be — and should be — reused for water supply or irrigation, this is a serious defect.

The ideal solution involves using stabilization ponds for treatment. These provide sufficiently long detention times for the pathogens to die off naturally, and they are very simple to operate and maintain. In suitable circumstances, the effluent from ponds or other treatment systems can be given a final "polishing" in wetlands, natural or artificial; this simple technique is relatively new, but it seems likely to be of increasing importance in future.

The main problem with stabilization ponds is that they require large areas of land, which are hard to find near big cities.

There are three remedies for this. The first is to subdivide the city and to use decentralized treatment, saving money in the process. The second is to locate the ponds slightly outside the urbanized area; when the city expands, the ponds can be "recycled" into the urban development, and the incoming sewage pumped to new ponds located further out. The third option is to adopt a slightly different form of sewage treatment. If stabilization ponds are used to grow duckweed (lemna), that in turn can be used to grow fish or, dried, as fish or poultry feed. This transforms sewage from a costly municipal headache into a revenue-earning source of protein. The productivity of the ponds is so high that this form of aquaculture is likely to be economically attractive until the land is almost overrun by urban development.

This form of sewage treatment — using duckweed or other plants such as water hyacinth — has existed more or less informally for many years. However, it is now being developed as a more systematic and formal means of solving the needs of major urban areas. For example, in Calcutta, a sewage-fed aquaculture system now provides 20 tons of fresh fish each day for sale in the city. A duckweed system in Bangladesh, treating sewage from 3,000 people, is costing less than 200 taka per day to run. The harvested duckweed (0.5 wet tons per day) has a value of about 500 taka per day as chicken meal; used for growing fish, its value is about 3,500 taka per day. This is perhaps the only flow-through wastewater treatment plant in the world that is making a profit from its operations.

CONCLUSION

Water shortage is already a reality in many developing countries, and it will get worse as populations increase. Rapid urbanization is leading to serious problems in providing and maintaining even basic water and sanitation services in many urban areas.

Emphasis needs to be placed on resource conservation and on efficient use, providing sustainable, affordable, and acceptable service for everyone rather than focusing on high levels of service for a select few, using technologies that fail after only a short time and that require heavy subsidies.

Any technology, at whatever level, that meets this criterion should be considered potentially suitable. There are more benefits from a modest system that works than from a luxury system that does not. This may mean starting with public standpipes for water supply and VIPs for sanitation, but these are still a vast improvement over doing nothing until "proper" systems can be installed. At the same time, people hope to be able to upgrade their systems as their circumstances improve, so this should, if possible, be an option.

Many communities in developing countries have ample supplies of certain resources but little access to imported skills and equipment. Sustainable projects therefore have to emphasize the development of local industry for manufacture and construction, and "robustness" rather than "reliability"; that is, when something breaks, it can be fixed quickly using locally-available resources.

Planners should "think small and local." Planning large centralized schemes assumes a degree of control over future urbanization that does not, and will not, exist in most developing countries, and there are probably no longer significant economies of scale to be gained by massive centralized projects.

Projects must be “circular,” not “linear.” Ideally, wastes should be treated and recycled where they are generated. It is no longer acceptable simply to export wastes, to be a problem for downstream communities.

Finally, water supply must be integrated with other urban environmental services. In particular, it is inextricably involved with sanitation, and these two must always be developed in parallel. However, sanitation will not be seen as a priority (and often will not work) without storm drainage, and storm drainage will not work without better solid wastes management.

Only a properly designed integrated package of services will provide optimal benefits and protect the environment. ❏

Bibliography

Azevedo Netto, José M. *Innovative and Low Cost Technologies Utilized in Sewerage.* Environmental Health Program Report No. 29, Washington, D.C.: Pan American Health Organization, March 1992.

Esrey, Steven A., et al. *Health Benefits From Improvements in Water Supply and Sanitation*. WASH Technical Report No. 66. Arlington, Va.: Water and Sanitation for Health Project, July 1990.

Feachem, Richard G., David J. Bradley, Hemda Garelick, and D. Duncan Mara. *Sanitation and Disease; Health Aspects of Excreta and Wastewater Management.* New York: John Wiley & Sons, Inc., 1983.

Franceys, R., J. Pickford, and R. Reed. *A Guide to the Development of On-site Sanitation*. Geneva, Switzerland: World Health Organization, 1992.

Hébert, Paul V., and Yniguez, Cesar. *Sensitivity of Water Distribution Costs to Design and Service Standards: A Philippine Case Study.* Technology Advisory Group Technical Note 16 (TAG TN16). Washington, D.C.: The World Bank, 1986.

Journey, W.K., and Andrew J. Macoun. *Wastewater Treatment With Duckweed Aquaculture*. Infrastructure Notes No. W&S SW-10. Washington, D.C.: The World Bank, October 1993.

Making Aquatic Weeds Useful: Some Perspectives for Developing Countries. Washington, D.C.: National Academy of Sciences, December 1976.

Mara, D. Duncan. *The Design of Pour-Flush Latrines.* Technical Advisory Group Technical Note 15 (TAG TN15). Washington, D.C.: The World Bank, 1985.

Mara, D. Duncan. *The Design of Ventilated Improved Pit Latrines.* Technical Advisory Group Technical Note 13 (TAG TN13). Washington, D.C.: The World Bank, 1984.

Otis, Richard J., and D. Duncan Mara. *The Design of Small Bore Sewer Systems.* Technical Advisory Group Technical Note 14 (TAG TN14). Washington D.C.: The World Bank, 1985.

Postel, Sandra. *The Last Oasis.* New York: W.W. Norton & Company, 1992.

Postel, Sandra. "The Politics of Water." *World Watch*, Vol. 6, No. 4, July-August 1993.

Tayler, Kevin, and Andrew Cotton. *Urban Upgrading: Options and Procedures for Pakistan*. Leicestershire, England: Water Engineering and Development Center, Loughborough University of Technology, 1993.

Whittington, Dale, Donald T. Lauria, Albert M. Wright, Kyeongae Choe, Jeffrey A. Hughes, and Venkateswarlu Swarna. *Household Demand for Improved Sanitation Services: A Case Study of Kumasi, Ghana.* Washington, D.C.: The World Bank, May 1992.

World Development Report 1992: Development and the Environment. Washington, D.C.: The World Bank, 1992.

World Health Organization. *Report of the WHO Commission on Health and Environment.* Document WHO/EHE/92.1. Geneva, Switzerland: World Health Organization, 1992.

World Resources, 1992-93. Report by the World Resources Institute in collaboration with the United Nations Environment Program and the United Nations Development Program. New York: Oxford University Press, 1992.

Contacts

American Water Works Association
6666 West Quincy Avenue
Denver, Colo. 80235 U.S.A.
Tel.: 303-794-7711

Board on Science and Technology
for International Development
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418 U.S.A.
Tel: 202-334-3585
Fax: 202-334-2660

World Health Organization
EHE/CWS
1211 Geneva 27
Switzerland
Tel: 41-22-991-2111
Fax: 41-22-791-0746

National Small Flows Clearinghouse
West Virginia University
Morgantown, W.Va. 26506-6064
U.S.A.
Tel.: 1-800-624-8301

Pan American Health Organization
525 23rd Street, N.W.
Washington, D.C. 20037 U.S.A.
Tel: 202-861-3313

United Nations Development
Program
Division of Public Affairs
Room DC1-1900
One United Nations Plaza
New York, N.Y. 10017 U.S.A.
Tel: 212-906-5000

Water and Engineering Development
Center
Loughborough University of
Technology
Leicestershire LE11 3TU, England
Tel: 44-509-222885
Fax: 44-509-211079

Water and Sanitation for Health
Project
1611 North Kent Street, Room 1001
Arlington, Va. 22209-2111 U.S.A.
Tel: 703-243-8200
Fax: 703-525-9137

World Bank
Water Supply and Sanitation Division
1818 H Street, N.W.
Washington, D.C. 20433 U.S.A.
Tel: 202-473-2595

Worldwatch Institute
1776 Massachusetts Avenue, N.W.
Washington, D.C. 20036 U.S.A.
Tel: 202-452-1999
Fax: 202-296-7365

Richard N. Middleton is vice president of Kalbermatten Associates, Inc.,
a water and wastes management advisory
service based in Washington, D.C. He served previously as head of the
Water Supply and Sanitation division with the World Bank.
Mr. Middleton has written and spoken widely on water resource planning and management.

Green Paper Series

Editors: Rick Marshall, Kathleen E. Hug
Design: Thaddeus A. Miksinski, Jr.

United States Information Agency
March 1995